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## BIM and QR-code. A synergic application in construction site management

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### Abstract

Construction phase still presents many difficulties and contingencies related to the project documents information management between the actors involved. Different studies investigated methods and models to optimize the operational management of the construction phase. Concerning workers' health and safety protection most of them focused on the development of on-site and in real-time control systems. Therefore, the authors identified the exigency of a prevention information system based on workers' involvement. To reach the aim three objectives have been identified: (1) the check of workers' training, (2) the definition of works operational procedures and (3) the schematization of the assembly/disassembly/use of site equipment and temporary structures. The developed system is characterized by a synergic application of BIM model and QR-code and it has been applied on a case study. At the same time a questionnaire has been developed and proposed to different subjects of the construction sector in order to evaluate the potential use of BIM model and QR-code. The field test has allowed to demonstrate the practical use of the tool, enhancing communication between the Client technical structure, the General contractor and sub-contractors, improving workers' integration and participation and allowing a better availability of on-site health and safety information and documents.

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### 1. Introduction

The purpose of the research presented in this paper is to improve, using Information Technology (IT), design and management of construction processes, with a particular attention to the construction site phase. IT instruments used

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are the Building Information Modeling (BIM) and the Quick Response Code (QR-Code) applied both to improve and speed up various aspects of the construction process. It has already been demonstrated the possibility and the consequent benefits of using IT methods, in particular BIM, for a better integration within different disciplines of the building process [1,2] and that BIM technology can be used as a starting point for safety planning and communication [3]. With the QR-code applications we have optimized the information flow between different actors involved, especially during the construction phases. The BIM and QR-code have been applied in a synergic way to a study case in order to analyze the effectiveness and the limitations of the system. The potentiality of the system has been evaluated also through a questionnaire proposed to different subjects of the construction sector.

The use of BIM technology for the representation of the construction site design, site planning and management have had, in recent years, some developments [3,4,5]. Concerning BIM technology applied to the execution phase management, some previous studies have been carried out [6]. These investigations have revealed that construction site BIM design during the planning phases allows to identify, with greater precision, the possible criticalities related to operational procedures. Thus, it is possible to increase the level of workers' safety, improving works production quality and avoiding improvised decisions in working progress. In the execution phase, the same BIM model can also be exploited by construction companies for a better site organization, in particular for a detailed development of the specific operational procedures. It is of paramount importance that the information related to design and operational management, collected in the BIM model, are available for all the figures involved in the construction process.

QR-code is a type of matrix barcode, also called two-dimensional barcode [7] with a great capacity to store data and equipped with a "self-correcting" function, that allows the reading of the code even if it is partially damaged, and a very simple structure. The most common method of database decoding consists of tablet/smartphone's apps dedicated to read the QR-code and quickly convert it in a URL. The widespread use of QR-codes was made possible thanks to all of these intrinsic qualities and to the presence of applications available for tablet or smartphone users. Thus, QR-code has been identified, together with BIM technology, as the instrument for the practical development of the proposed system.

## **2. QR-code and BIM in construction site**

The prevention information system is characterized by a synergic application of BIM model and QR-code. To have a better design and management of the construction process three objectives have been identified: (1) the check of workers' training, (2) the definition of works operational procedures and (3) the schematization of the assembly/disassembly/use of site equipment and temporary structures. Below a summary of the three applications referred to the case study is presented with some examples. The case study consists in a restoration site of a building tower located in the center of Milan. The tower is characterized by 28 floors above ground and 2 underground floors. Main works are concrete pillars reinforcement and metal carpentry assembly.

### *2.1. Check of workers' training*

One of the main criticalities is related to the data availability about workers' training. To achieve the object, we have developed several data sheets that summarize the significant worker information in order to not waste time looking for them in the paper archives of the construction company. For each of the summary sheets, a QR-code is created and the code is placed on the tag of the corresponding worker or on the respective hard hat. So, thanks to a scan of the code with a smartphone or tablet, that links to the database URL, it is possible, for example, to control the authorization to a specific equipment or processing, easily and with a great rapidity. On the same online page containing summary sheets, links that lead to the original training certificates are available. Below an example of application of the system to the case study is presented. Figure 1 represents the worker tag with the application of QR-code, while figure 2 represents the data sheet that summarizes worker information. Data sheet, as indicated, is organized in different parts in order to have a structured information system that simplify the verification of workers' data and allows a faster comprehension from the inspection body.

<b>Marco Rossi</b>		Worker name
		Application of QR-code
		Worker picture
<b>Company: Rossi Construction S.p.a.</b>		Company name

Fig. 1. Worker tag with the application of QR-code.

WORKER DATA SHEET		
SURNAME, NAME: Rossi, Marco		Personal Data
Born: 23/06/1962		
Tax code: RSSMRC62H26G119Z		
Understanding of spoken Italian	<input checked="" type="checkbox"/> Good <input type="checkbox"/> Sufficient <input type="checkbox"/> Limited	Language comprehension
Reading skills of the Italian language	<input checked="" type="checkbox"/> Good <input type="checkbox"/> Sufficient <input type="checkbox"/> Limited	
Company: Rossi Construction S.p.a.		
Employee: 24/09/2001	Employee register: 352	Company data
Construction worker from: 1978	Position: 4° level worker	
Safety training: 2009	Health supervision: <input checked="" type="checkbox"/> 2012 <input checked="" type="checkbox"/> 2013 <input type="checkbox"/> 2014	
Task:	Trained to the task: 2007      Practiced to the task: 2008	Safety training
Assign to the first aid	<input checked="" type="checkbox"/> construction school <input type="checkbox"/> support by	
Task:	Trained to the task: 2008      Practiced to the task: 2009	
Assign to the fire prevention	<input checked="" type="checkbox"/> construction school <input type="checkbox"/> support by	Authorizations
Task:	Trained to the task: 2008      Practiced to the task: 2009	
Supervisor D.lgs. 81/2008	<input checked="" type="checkbox"/> construction school <input type="checkbox"/> support by	
Authorized to assembly:	<input checked="" type="checkbox"/> Trestle scaffold <input checked="" type="checkbox"/> Mobile scaffold <input type="checkbox"/> Guardrail	Note
Authorized to use:	<input type="checkbox"/> Automotive machines <input type="checkbox"/> Aerial handling machines <input type="checkbox"/> Motorized equipments for elevated working <input type="checkbox"/> Fixed equipments for processing and semi-finished production <input type="checkbox"/> Electromechanical tools <input type="checkbox"/> Personal protective equipment	
Other certificates:	<input checked="" type="checkbox"/> Assign to the first aid <input checked="" type="checkbox"/> Assign to the fire prevention <input type="checkbox"/> Lashing load	
Note: Refresher assign to the first aid 2011; Refresher assign to the fire prevention 2012		
Date: 15/03/2014	Employer signature:	

Fig. 2. Data sheet that summarizes the worker information.

## 2.2. Definition of works operational procedures

The next analysed aspect is related to the definition of schematic operational procedures in order to easily transfer them to workers. Generally, construction companies documents, in which operational procedures are contained (i.e. Operational Safety Plans), have a lexicon not always understandable for workers. Thus, these documents are not suitable for a practical use on construction site. Therefore, it has been developed a "form" as a means of communication with workers, characterized by simplicity, linear logic and clarity. A specific group of forms constitutes a complementary and operational procedure that should be included in the Operational Safety Plan. In the forms are attached some three-dimensional images (see figure 3), extracted from the construction site BIM model, that represent workstations and activities in order to allow workers' immediate comprehension of the correct operating sequence. The information contained in the forms are structured in a systematic way that allows the construction site manager, or otherwise the employees of a specific company, to gain a practice for data acquisition. The forms are included in the company online database, hence a QR-code is associated to each form. By affixing a tag with the QR-code to the technical element, object of processing or adjacent to it, any subject can display on its smartphone or tablet all the information contained in the forms. In the case study, for example, a tag has been fixed on a concrete pillar and near the metal carpentry. Next figure represents one sheet of the group that gives the operational procedures for the pillar reinforcement. As in the previous sheet, the document is organized in different parts, as indicated, in order to have a structured information system that simplify the comprehension from workers.

As explained, the prevention information system has been applied directly on site, involving in particular construction company. Figures 4, 5, represent some significant moments of the system testing, demonstrating the practical use of the tool and the company interest and involvement.

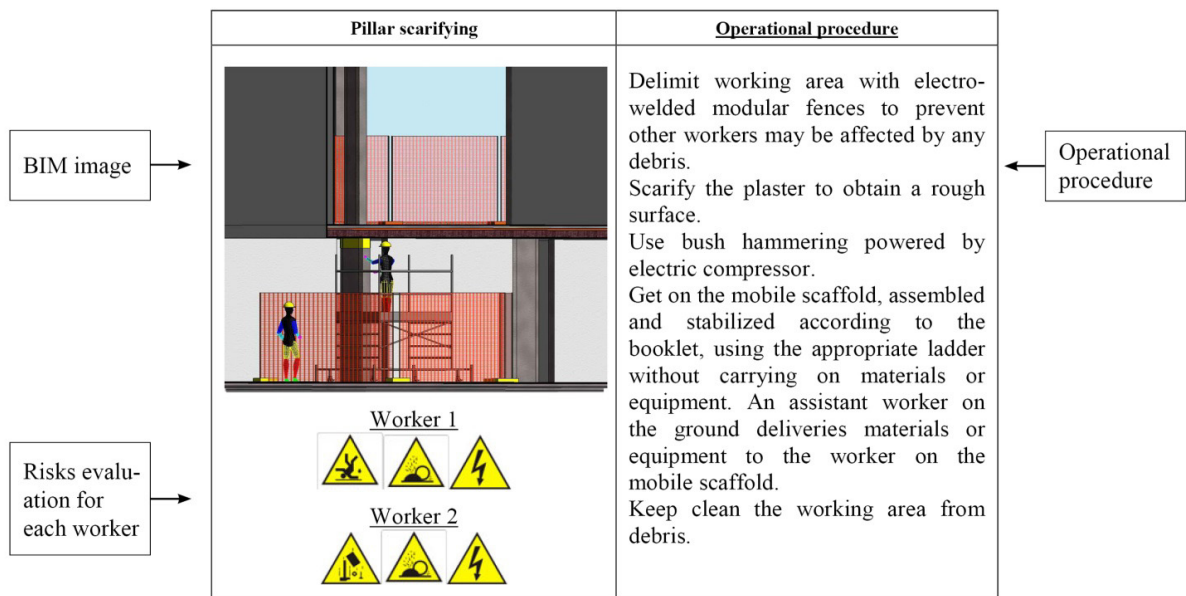


Fig. 3. Pillar scarifying operational procedure.

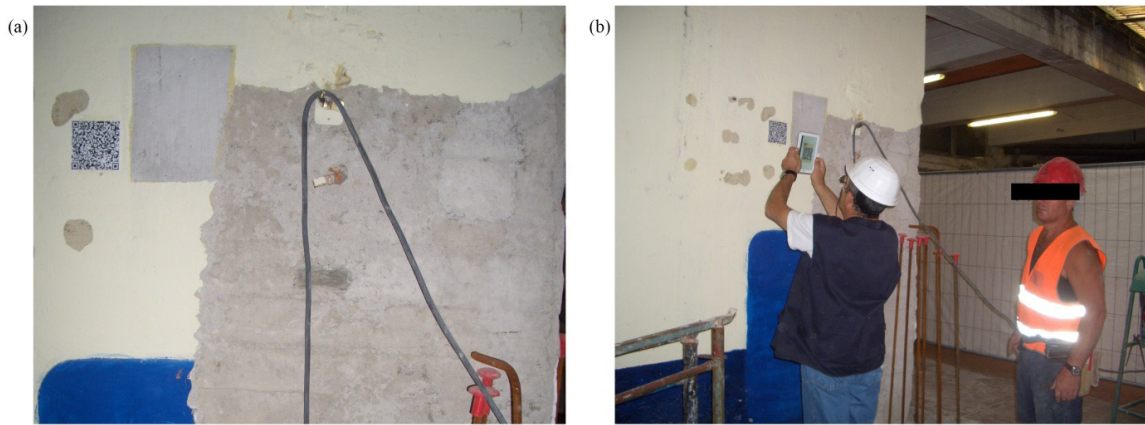


Fig. 4. (a) A tag with the QR-code on the technical element (pillar); (b) Scan of the QR-code with a tablet by the site foreman.

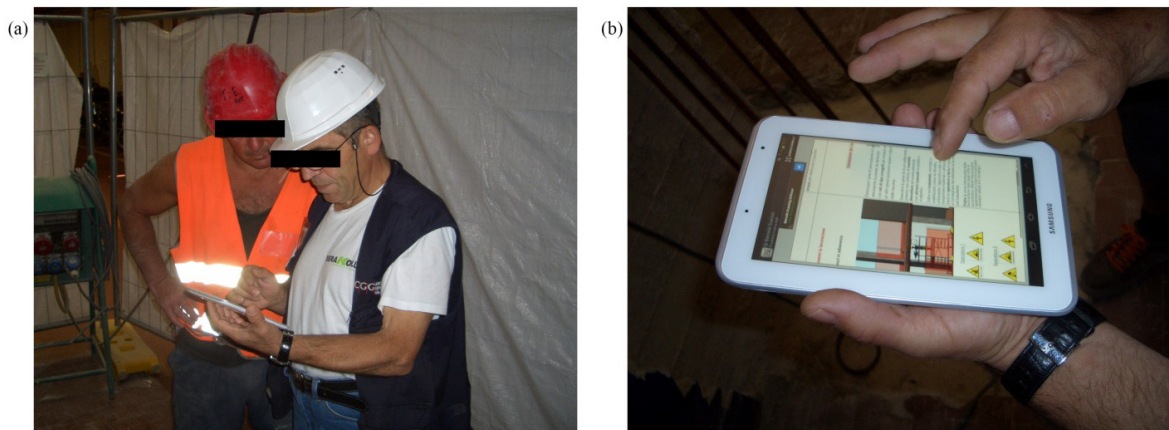


Fig. 5. (a) Illustration of the operational procedures by the site foreman to the worker; (b) Operational procedure on the tablet

### 2.3. Schematization of the assembly/disassembly/use of site equipment and temporary structures

In order to schematize the assembly/disassembly/use of site equipment and temporary structure, another application of QR-code in constructions site has been its placing directly on the object that have to be used. This management process provides that not only equipment/temporary structures handbooks are available in the site offices, but also each equipment/temporary structure is accompanied by the respective handbook in the specific workplace. In this way, two significant problems have been solved: handbooks deterioration and their consultation in real time. As an example, a developed form has been the one for a mobile scaffold (see figure 8), in which all the information necessary for the proper installation, use and dismantling are summarized and being accessible thanks to the technology of the QR-code. The form structure has been developed starting from the typical information contain in temporary structures handbook, but summarized in order simplify the information transmission and optimize the usability of the structure on site.



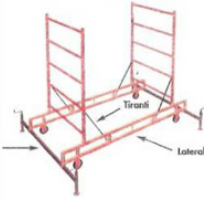
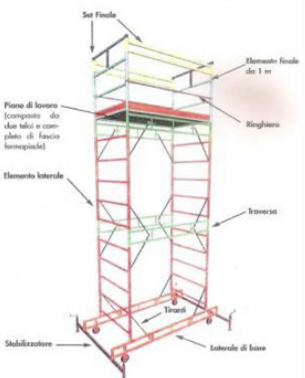
<b>MOBILE SCAFFOLD</b>	
<b>Assembly instructions</b>	
<p>Check the integrity and the perfect functionality of all mobile scaffold components before use them.  The mobile scaffold must be assembly by two people at least and always using PPE provided.  <u>PPE to be used:</u> Hard hat, Gloves, High visibility clothing</p>	
	<p><b><u>Assembly base section</u></b></p> <p>To connect two base side elements and insert a pair of orthogonal elements in the slots.  To connect in the upper part two opposite elements with a pair of cross elements (tie rods facing inward).  To attach the tie rods to the elements and lock it by the screw.  To install the stabilizer bars at side of the base and stabilize the structure by the leveling screw.  To lock the wheels by appropriate wedges or brakes.</p>
	
<b>Use instructions</b>	
<p>To move the mobile scaffold must lift the removable part of the stabilizer bar and to must reduce the height to a maximum of two bays.  The movements can be done only in longitudinal and cross direction of plant.  During the movement, on the mobile scaffold must not be any people or things.  Before each use (and also after each movement) should verify the correct assembly of the mobile scaffold and that is in a vertical position.</p>	
<b>Disassembly instructions</b>	
<p>The disassembly of the mobile scaffold must be performed in reverse sequence of that of the assembly.</p>	

Fig. 6. (a) Illustration of the operational procedures by the site foreman to the worker; (b) Operational procedure on the tablet

### 3. Illustrations

What has been described and applied in the specific case study shows how the adoption of QR-code, together with BIM technology, has been absolutely achievable and easily enjoyed. However, in order to analyze the wider development of this system and evaluate its potential use, it has been decided to contact several professional figures -users-, from both the companies' world and the freelancers' world, and interview them through a questionnaire. Regarding construction companies, employers, managers and supervisors have been interviewed, while concerning freelancers the research has involved in particular safety coordinators, construction supervisor, project managers and project supervisors. Figure 9 shows the percentages of interviewed figures, for a total percentage of 24% related to construction companies' world and 76% related to freelancers' world. By analyzing and comparing the different answers, it has been possible to evaluate the strength and weakness of the proposed system in order to improve and further develop it.

The questionnaire is composed by 12 questions, accompanied by some examples of system application, that have been structured in the following way:

- The first three questions are related to the usefulness of the system from the point of view of figures belonging to construction companies and related to management roles, such as construction site managers or foremen. For each question it is required a score association to the system benefits. An example of question is: “Can be useful for the site manager or foreman to access via QR-CODE to text or images of an operating procedure using a tablet/smartphone?”.
- The next four questions are addressed to evaluate the system utility form the point of view of figures belonging to construction companies, which have a role of control on construction site, such as health and safety managers, workers health and safety representatives or sometimes the same employers. An example of question is: “Can be useful to access via QR-CODE to an operating procedure in order to control its correct implementation using a tablet/smartphone?”
- The following three questions identify three ranges of work amounts related to the applicability of the system. In particular, works have been divided under € 500,000, between € 500,000 and € 5,000,000 and over € 5 million.
- Finally, the last two questions are related to the practical applicability of the system. In fact, it needs tools, such as tablets or smartphones, that are common between business men or professionals but not among construction site workers. Is then requested an opinion about the likelihood that construction site managers or foremen will be equipped by the aforementioned instruments respectively from now until the next 2/4 years.

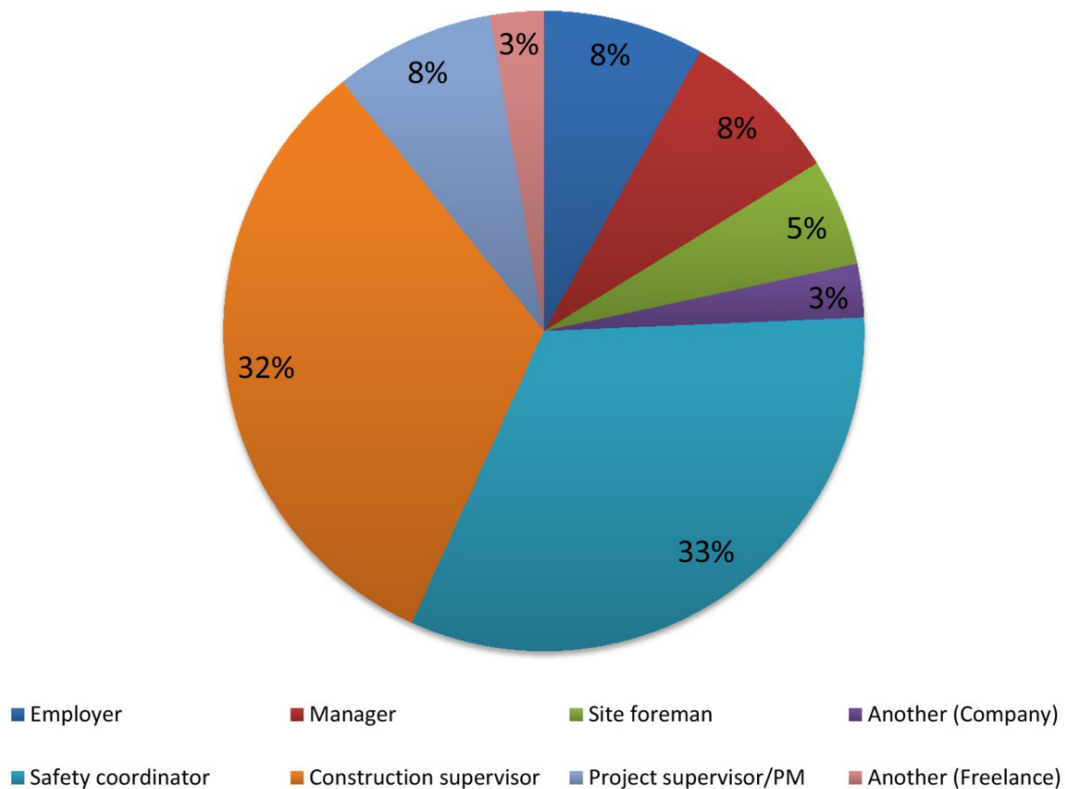


Fig. 7. Survey sample

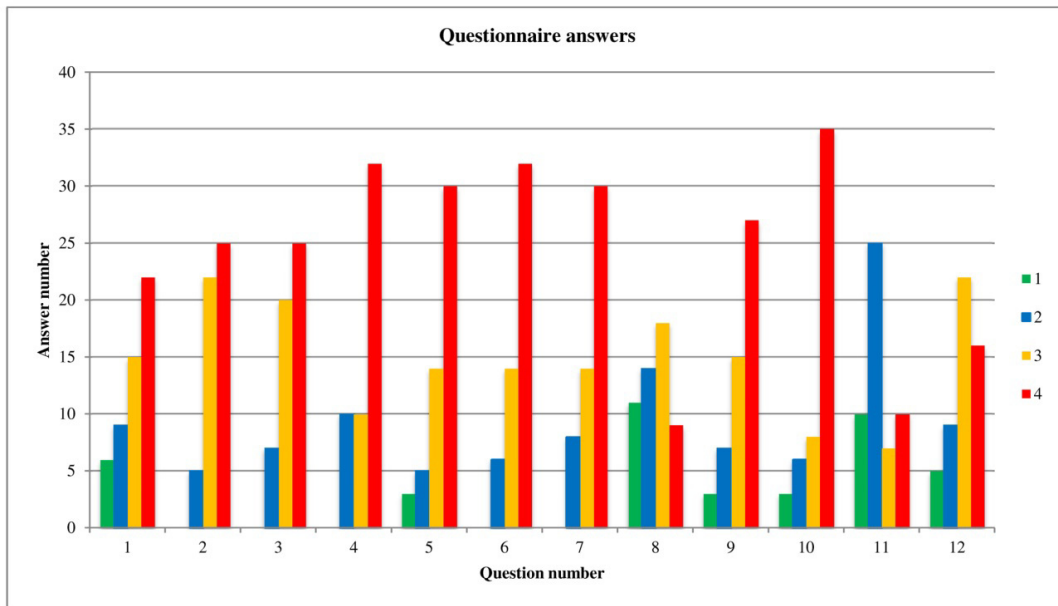


Fig. 8. (a) Illustration of the operational procedures by the site foreman to the worker; (b) Operational procedure on the tablet

For each question, a spectrum of responses has been provided by assigning a score from 1 to 4, where 1 means little useful/probable and 4 means very useful/probable. Thus, it has been possible to analyze the different respondents opinions, without forcing them to give a clear yes or no but giving the opportunity to show the different shades of their reasoning. At the end, a number of 52 respondents questionnaires have been collected. From the different answers, summarized in the graphic above (see figure 10), we can conclude that the majority of respondents have considered very useful the overall presented system, differentiating however its applicability depending on the different types of construction site. Indeed, in the questions about the usefulness of the system for small sites (question 8), the responses have been very different from those regarding big sites. Most of all the respondents has felt that the system would be beneficial if the initial investment is quickly recovered from the speeding up of operations on-site, otherwise they have felt the investment required by the system unaffordable for small sites. Furthermore, with the increasing amount of works the percentage of positive responses increases until it reaches the 78% of responses with the highest available rating. Finally, with regard to the provision of tools, such as smartphones and tablets, in the next two years, the respondents have indicate that it is unpredictable, especially considering the economic crisis that is sweeping the country, while they are more optimistic for the dissemination of these tools in the next 4 years.

#### 4. Conclusions

Referring to the questionnaire, the system is generally evaluated positively, with some limitations that make it more useful and applicable in big construction sites under the organization of structured construction companies, more difficult to apply in small construction sites. Professionals interviewed, even if with some difference, have appreciated the proposed system and they have considered it gradually implemented. Indeed, the system presents the advantage that, once developed, it has to be only easily updated, and it will be even more simply to implement according to the IT knowledge progression. Moreover, in the case study the company, that has tested the system, has been positively collaborated, showing appreciation for it. Thus, the case study illustrates the practical use of the developed prevention information system, characterized by a synergic application of IT instruments, QR-code and



BIM technology. It has been demonstrated that the system, based on workers' involvement, aim at reaching the three identified objectives: (1) the check of workers' training, (2) the definition of works operational procedures and (3) the schematization of the assembly/disassembly/use of site equipment and temporary structures. In conclusion, the system is developed and structured in order to have a better design and management of the construction process during the execution phase, enhancing communication between the Client technical structure, the General contractor and sub-contractors, allowing a better availability of on-site health and safety information and documents.

## References

- [1] C. Feng, Y. Ho, An information-flow-based organizational framework to streamline the process of employing BIM within construction projects, Creative Construction Conference, Budapest, Hungary, 2013.
- [2] H. Zhenzhong, Z. Jianping, D. Ziyin, Construction process simulation and safety analysis based on Building Information Model and 4D Technology, Tsinghua science and technology, 13(1), 2008, pp. 266-272.
- [3] K. Sulankivi, K. Kähkönen, T. Mäkelä, M. Kiviniemi, 4D-BIM for Construction Safety Planning, W099 - Special Track 18th CIB World Building Congress, Salford, UK, 2010.
- [4] N.C. Babic, P. Podbreznik, D. Rebolj, Integrating resource production and construction using BIM, Automation in Construction, Elsevier, 19(5), 2010, pp. 539-543.
- [5] C. Harty, D. Throssell, H. Jeffrey, M. Stagg, Implementing building information modelling: a case study of the Barts and the London hospitals, 13th International Conference on Computing in Civil and Building Engineering, Nottingham, UK, 2010.
- [6] M.L. Trani, B. Bossi, M. Cassano, BIM technology for restoration site design, Research, Development, and Practice in Structural Engineering and Construction, Vimonasit, V., Singh, A., Yazdani, S. (eds.), ASEA-SEC-1, Perth, Australia, 2012.
- [7] Y. Liu, J. Yang, M. Liu, Recognition of QR Code with Mobile Phones, Chinese Control and Decision Conference, Yantai, Shandong, 2008.